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Problems and Potentials of Permanent Raised Bed Cropping Systems in Pakistan

Ghani Akbar[1], G. Hamilton[2], Zahid Hussain[3] and M. Yasin[4]

ABSTRACT: Water is one of the most important inputs in agriculture. As the available freshwater resources are scarce so it is important to utilize it efficiently. The losses need to be controlled in the whole irrigation system starting from its source till its final application for crop production. Permanent raised bed cropping system could be practiced to save water at the field application level and also have the capability to enhance production. The available permanent raised bed cropping system machinery used in this study was imported from Australia under a research project of Pakistan Agriculture Research Council (PARC) in collaboration with the Australian Centre for International Agricultural Research (ACIAR). Two permanent raised bed machinery sets were given to two clusters of farmers and crops were sown on permanent raised beds in wheat-maize cropping pattern. Each cluster consisted of about 25 farmers. The data collected from the farmers show that there was about 36% (130 cm furrow centre gap) water saving for wide beds and about 10% for narrow beds (65 cm furrow centre gap) and grain yield increase of about 6% for wheat crop and 33% for maize crop. The percent of cluster farmers that have adopted the technology on seasonal basis are in the range of 35% for wheat and 77% for maize. The farmers that have adopted the permanent raised bed technology for both crops and are still practicing it are about 16% of both clusters farmers. The reasons for less adoption of technology inside the cluster farmers were less weeds control, non-compatible cropping pattern, no use of recommended dozes of all farm inputs, small farm sizes, problems in tenancy rules, lack of awareness and technical skills of farmers. Other reasons that needs to be resolved for adoption throughout the country might be the lack of properly made raised bed machinery availability up to the satisfaction of farmers, need for mechanization of farming system from sowing to harvest *etc*.

KEYWORDS: Permanent raised beds, renovation, water productivity, yield, water saving.

INTRODUCTION

Agriculture constitutes the largest sector of our economy. Majority of our population, directly or indirectly, depends on this sector. It contributes about a quarter of our Gross Domestic Product (GDP) and accounts for about half of employed labour force and is the largest source of foreign exchange earnings. Currently agriculture in Pakistan is facing a very severe threat of shortage of irrigation water, because of traditional methods of cultivation, less trend towards agricultural mechanization, lack of farmers' awareness from advance methods of farming, lack of better quality seeds, more input cost that is out of the reach of poor farmers, less opportunities for getting better prices of farm products, smaller farm sizes, water logging and salinity problems etc. All these factors have made agriculture less profitable and more risky. Wheat and maize are the main cereal crops. The average yield of wheat is 2,800 kg/ha (GoP, 2007), which is among the lowest in the world.

Pakistan has a total area of about 79.61 Mha, 21 Mha of which is cultivated, out of which 17 Mha is irrigated land. The whole of Pakistan except a narrow belt in the north is arid to semi arid. Only 9% of the country receives more than 508 mm of rain per year. Whereas pan evaporation in the

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Indus plains ranges from 1300 mm in northern Punjab to 2800 mm in Sindh (Qureshi and Barret-Lennard, 1998). It is therefore essential for crop production that crop water requirement should be fulfilled by applying irrigation. Currently irrigated agriculture accounts for about 90% of Pakistan's agricultural output (Barral, 1994). Pakistan has the largest contiguous irrigation system in the world i.e. the Indus Basin Irrigation System (IBIS). Shortage of canal water is one of the major limitations in the Indus basin irrigation system. The Indus basin is operating at less than 40% efficiency (Ministry of food, Agriculture and Cooperatives, 1984). The overall scarcity and non availability of water at the right time and inefficient utilization of the available water appear to be the leading factors restricting expansion in irrigated areas and causing the gap between the actual and potential yields (Chaudhry and Ali, 1989). Method of irrigation plays the most significant role on how efficiency of water can be increased. Most of the farmers are using the traditional method of basin/flood irrigation. Low application efficiencies reported in the Indus basin are result of over irrigation, improper irrigation methods, unscientific irrigation scheduling and unlevelled fields (Chaudhary *et al.,* 1994). All the above-mentioned facts necessitate the need for improving efficiency of water use at the farm level. The efficient use of limited irrigation water obtained from different sources is possible by adopting efficient irrigation methods. Raised beds planting technique could help in reducing irrigation requirements of crops and increase crop production in salinity affected areas. This method is appropriate for soils having low permeability, seasonal water logging, salinity and shortage of water supply (Qureshi and Barrett-Lennard, 1998).

Permanent Raised Bed Planting

In this technique the field is divided into narrow strips of raised beds separated by furrows. The crops are planted on the bed surface and irrigation water is applied through the furrows. The bed surface remains almost dry and the lateral water movement fulfills the crop water requirement. The infiltration rate of the furrow bottom remains almost zero due to compaction developed by tractor and machinery movement and irrigation water which facilitates the lateral water movement of irrigation water into the bed area. Generally, a single row is planted on the top of each bed for row crops like maize, soybean, cotton, sorghum, sunflower and dry bean, 1-2 rows per bed are planted for crops like chickpea and canola, but 2-4 defined rows, spaced by 15-30 cm depending on bed width are used for wheat (Aquino, 1998). Generally the farmers practicing the bed planting technique are currently removing or incorporating the crop residues, destroy the beds by tilling the soil, and make the beds again before the next crop.

In permanent raised bed technique the bed-furrow system once developed is not destroyed seasons after seasons. The beds are only renovated and not misplaced. The renovation operation consists of only using a bed renovator. The bed renovator consists of two or three furrowers depending on the size of the raised beds for cleaning the furrows and two horizontal blades that cuts the bed at the base of crop root zone without disturbing the top of the bed. As experience has been gained with bed planting and appropriate implements have been developed, farmers who grow crops on beds can now simply reshape the beds before planting the next crop and retain all or part of the crop residues on the surface, a practice referred to as "Permanent Raised Bed Planting".

Most of the developed world as well as some of the developing countries have adopted this method of planting. In the Yaqui valley of Mexico, the birthplace of the green revolution in wheat, currently 95% of valley farmers plant all crops on beds with furrow irrigation. In China Shandong province in yellow river basin bed planting has grown from a few test plots in 1998 to more than 26000 ha today. There are now over 28 million hectares of zero till seeding in Latin America with the bulk concentrated in the southern cone countries of Brazil, Argentina and Paraguay (Derpsch, 2001)

The permanent raised beds are widely used in Australia for both irrigated and dry land areas. Production increase of 20-100% was achieved under both areas (irrigated and dry lands). Irrigation application efficiencies were improved. The degraded lands were rehabilitated through improving soil physico-chemical characteristics. Furrow bed system had also helped prevent

water logging to a significant extent as excessive water can be drained more efficiently compared to basin/flood irrigation. Adaptation of raised beds technology has been proved successful on farms, which suffer frequent water logging over significant proportion of the cropping area. Raised bed farming is currently estimated to cover about 20,000 hectares in Western Australia (WRRI, 1999). The survey conducted by IIMI-Pak indicated that farmers were adopting furrow-bed system for cotton and expecting 20 to 50% saving in water in addition to increase in yield of seed-cotton (Barkhout *et al*., 1997). Some early works conducted in Pakistan have shown that non-permanent beds/ridges and furrow irrigation resulted in an increase of 20-25% in the yield of wheat. Similarly, an increase of 17-48% for cotton and 45% for canola yield were reported with 25-50% water saving.

Raoof *et al*., (1993) determined a maximum consumption of irrigation water for basin and maximum water use efficiency for raised beds. For maize crop the water use efficiency in beds was 79% higher than flat, while in wheat it was 91% greater than basin. They also determined 6% greater yield for bed than for flat basins.

Stone and Nofziger (1993) conducted an experiment on a Hollister clay loam soil at Altas, Oklahoma, USA. They gathered data for more than 18 years for growing cotton on wide space furrows. They concluded that water use efficiency for wide spaced furrow was 15% greater than every furrow irrigation. Yield of wide spaced furrow was 48% higher than every furrow irrigation.

Hassan *et al., (2005)* conducted experiment on wheat-maize cropping pattern from 1999 to 2004 using permanent raised beds (180 cm between centre of furrows) as compared to flat basin at Mardan, NWFP, Pakistan and have reported average yield increase for permanent raised bed of 30% for maize and 13% for wheat, average water saving of 32% for maize and 36% for wheat, average increase in water productivity of 65% for maize and 50% for wheat, average increase in net economic benefit of 54% for maize and 35% for wheat as compared to flat basin. Soil physical parameters like bulk density, infiltration and organic matter also showed improvement under permanent raised bed as compared to flat basin.

Sayre, (2002) reported that wheat and maize are planted in many parts of the world on beds. In some areas new beds are formed for each crop, and in some area permanent beds are used. He reported six countries of Asia and mentioned that bed planting on average saved 29% of water as compared to flat.

Farmers in Pakistan, India and Bangladesh are under great pressure to intensify and diversify their cropping systems, are now improving the system. They value the flexibility that bed planting offers for crop rotations and intercropping. They benefit from higher profits and better nutrition by planting high value crops such as mung bean, potato, pulses, cotton, tobacco and maize with the system. The development of appropriate rice varieties for transplanting or seeding directly into beds should give farmers even more options and operations.

Materials and Methods

The study area is located at Mardan in North West Frontier Province (NWFP) of Pakistan, at 34:12°E latitude and 73:03°N longitude. It falls in the semiarid zone for both summer and winter seasons with mean seasonal rainfall of 250 mm in summer (May-September) and 300 mm during winter (October-April).

Two clusters of farmers were made at Mardan district of NWFP Province. Each cluster consists of 20-25 farmers. Each cluster was provided a set of permanent raised bed former and seeder along with tractor and other equipments under a research project in Collaboration with Australian Centre for International Agricultural Research (ACIAR) as interest free loan payable in equal seasonal installments. Some revolving fund for the purchase of seed, fertilizers *etc.,* were also provided. The farmers were trained and all necessary technical guidance was provided in the use of permanent raised bed machinery. Wheat and maize crops were sown for three consecutive years in a wheat-maize cropping pattern in their respective seasons (November 2004 to May 2007). The machines were capable of making wide bed 130 cm and Narrow bed 65 cm (gap between centre of two furrows).

Data Collection and Analysis

Data regarding number of farmers using permanent raised beds, crops yield, weed control, irrigation, and fertilizer *etc.,* use was recorded during the whole study period. The farmers concerns and other related issues were also recorded.

RESULTS AND DISCUSSIONS

Seasonal Conditions

The seasonal variations have a very crucial and important effect on the production parameters of a crop. Rainfall can delay the sowing of wheat crop, which have negative effects on crop yield. The temperature is very low and evaporation losses are minimum during sowing period of wheat and if weather is rainy then it become very important to get the proper soil moisture favourable for better seed bed preparation. This was observed in the year 2006-07. The temperature plays a very important role on the health of the crop. If the temperature is low and weather is foggy then it can produce negative effects on the crop health. Negative effects were observed on wheat 2004-05 when the crop was affected by yellow rust disease due to low temperature that remained for many days. Total rainfall for the crop seasons during 2004-2007 is given in Figure 1. Total rainfalls were 353.5, 113 and 440.32 mm in the years 2004-05, 2005-06 and 2006-07, respectively for wheat crop. For maize crop, the total rainfall was 416 and 181 mm during 2005 and 2006, respectively.

Grain Yield

Grain yield data was collected from farmers in both clusters. Average number of farmers per season for all the wheat seasons was about nine while for maize they were 19. Total number of farmers in both clusters was about 50 in number. The farmers have observed about 5.8 and 4.5% increases in average yield for wheat crop on wide beds (130 cm) and narrow beds (65 cm), respectively as compared to traditional flat flooding. The farmers have also observed about 33 and 31% increases in average yield for maize crop on wide beds (130 cm) and Narrow beds (65 cm), respectively as compared to traditional flat basin. The grain yield seasonal variations are summarized in Figure 2 and 3 for wheat and maize crops, respectively.

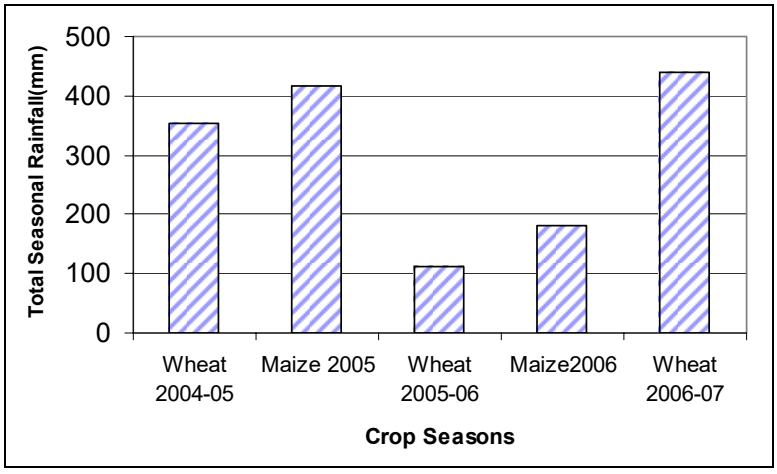

Figure 1: *Seasonal Rainfall During the Experimental Period*

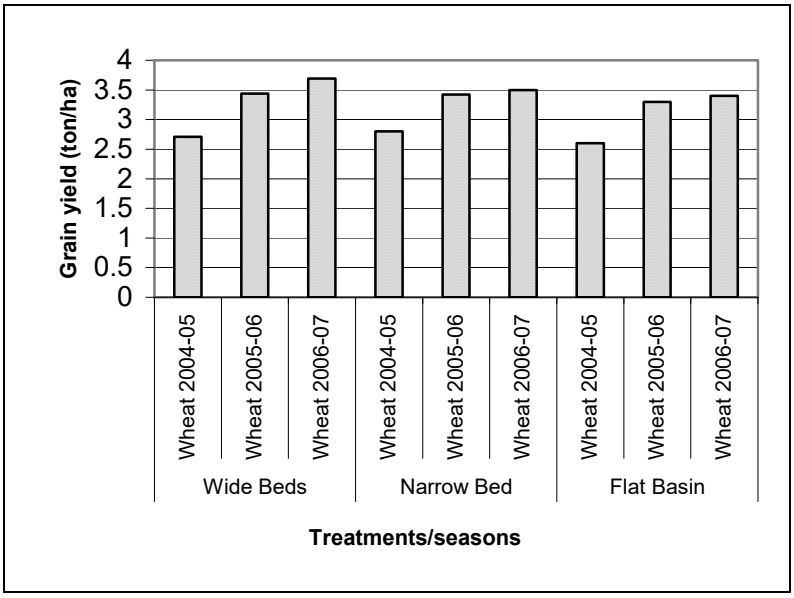

Figure 2*: Wheat Crop Grain Yields of Different Treatments on Farmers' Fields*

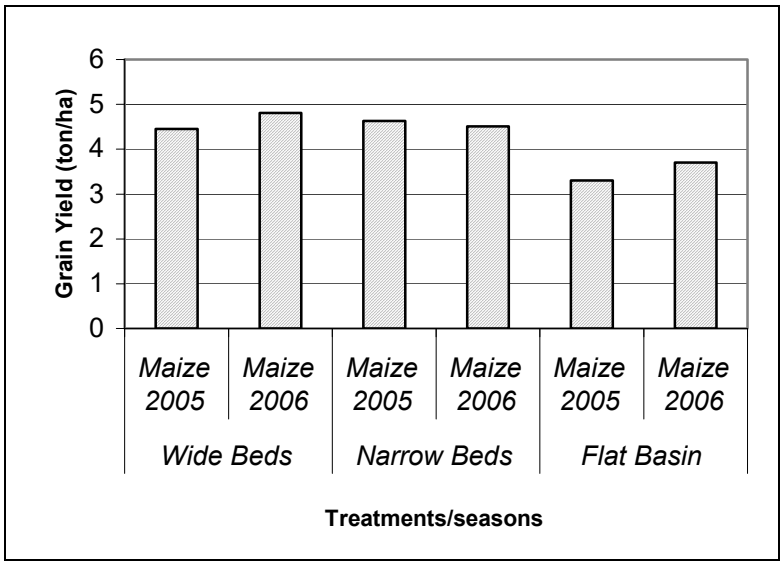

Figure 3: *Maize Crop Grain Yields of Different Treatments on Farmers' Fields*

Water Saving

The irrigation data for all the crops were collected from all the farmers. All the farmers were satisfied with the saving in irrigation water using raised beds. The average water saving in farmers' field as compared to traditional flat basin (flooding) was in the range of 35% for wide beds and 9.6% for narrow beds for wheat crops and in the range of 36%, 7.9% for maize crops, respectively. The irrigation time per unit area was based on about 1 cusec discharge of watercourse common in the area. The wheat crops were applied three to four irrigations while maize crop was applied seven to eight irrigations. It was learnt during the study period that during wheat crop season generally the temperature is low in the initial four to five months of crop season and evaporation losses

are minimal thus rainfall mostly fulfill the irrigation requirements of wheat crop and irrigation application is less common. The canals are also closed for two to three months. That is why the farmers are less attracted to raised beds for wheat crop because of their less demand for water saving. But during maize season the temperature is at its peak in June to September and each farmer is in need of water for irrigating his fields. Generally, the canal water is less and evaporation losses are more. Also maize crop especially the hybrid variety needs more water so the farmers are in need of using their limited irrigation water more efficiently to meet their crop water requirements. Thus they prefer to sow their maize crop on raised beds. It was learnt that the farmers have shown more interest in wide beds of 130 cm than narrow beds of 65 cm because of more water saving in wide beds. The irrigation time data for different treatments are shown in Figures 4 and 5 for wheat and maize crops, respectively.

Permanent Raised Bed Technology Adoptability

The permanent raised bed technology was new for the farmers. The farmers were using seasonal non-permanent ridges for row crops like maize, tobacco, sugarcane, sugar beat and some vegetables. But they have not ever used raised beds for wheat crop. That is why they hesitate to sow wheat crop on raised beds. They have a concern of land loss in furrows especially for wheat crop. However, some farmers were agreed to sow their wheat crop on raised bed with the existing raised bed machinery. It can be determined that still adoption of raised beds for wheat crop is very weak as compared to maize as shown in Figure 6. The average percentage of cluster farmers that have sown wheat crop on raised beds not necessarily permanent raised beds are around 35% while for maize they are 77%. The percentage of farmers that have adopted the permanent raised beds for both crops and are still practicing it are around 16% of both cluster farmers. The wheat crop adoption in the initial year of 2004-05 is more as compared to the latter years due to the reason that more wheat crop was sown in the area in 2004-05 than the latter years. Further more, in wheat 2004-05 season more rainfall occurred and irrigation application was less. The wheat 2004-05 crop was affected by yellow rust disease in almost the whole province of NWFP that have caused reduction in wheat crop sowing in the latter years especially in Mardan cluster areas.

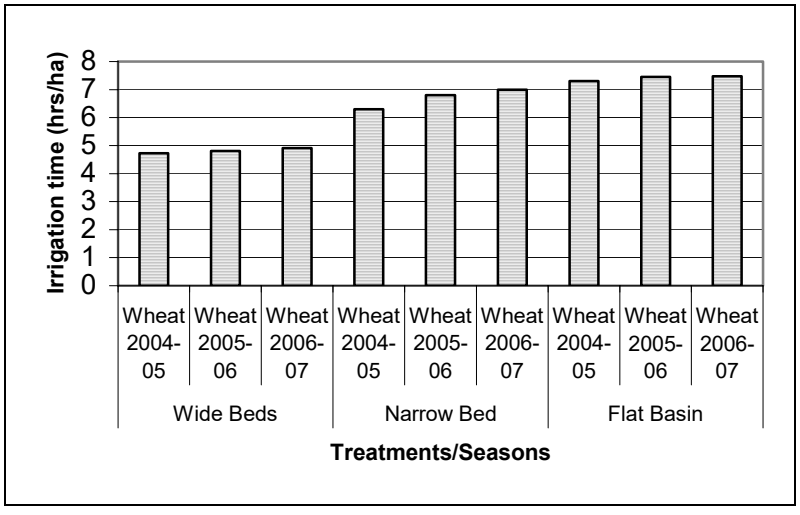

Figure 4*: Wheat Crop Irrigation Times of Different Treatments on Farmers' Fields*

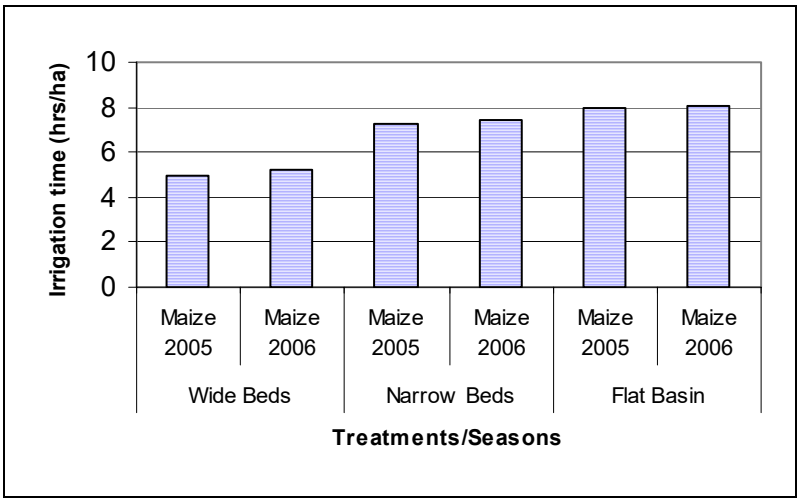

Figure 5*: Maize Crop Irrigation Times of Different Treatments on Farmers' Fields*

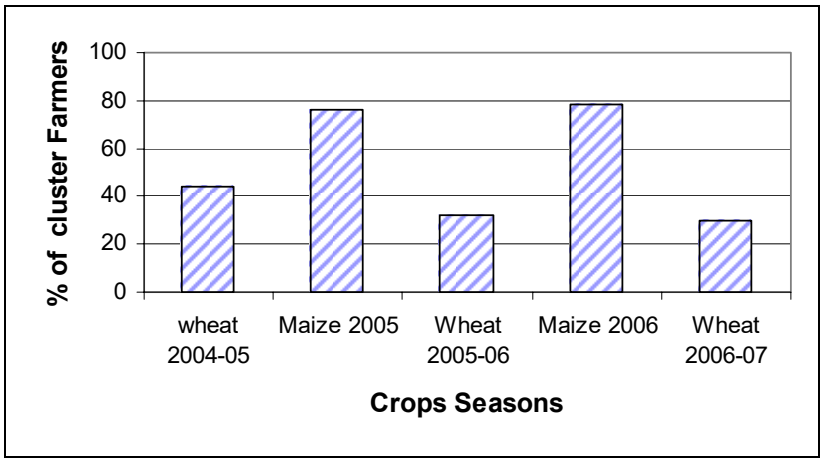

Figure 6: *Adoption of Permanent Raised Bed Technology wit h in the Cluster Farmers*

There are many reasons that limit the adoption of permanent raised bed cropping system. They are summarized below:

Limitation in adoption of Permanent Raised Beds Cropping System

Based on the study of cluster farmers and outside cluster farmers, the main reasons restricting the adoption of permanent raised bed cropping systems were determined from the farmers. This technology can be developed and its adoption could be stimulated in the country by resolving these issues. The main issues are as under:

Lack of Proper Permanent Raised Bed Machinery

In Pakistan, one of the main reasons of less raised bed farming is the non-availability of proper raised bed machinery. The farmers are using traditional methods of manual and animal bed making for some raw cash crops like tobacco, maize, cotton *etc.* and some vegetables. Some farmers have started using ridgers with tractor for narrow beds/ridges making. But the farmers are in need of proper bed making, sowing, fertilizing, spraying/weeding and harvesting machinery. The

farmers could not manage to sow or harvest their crops at proper time, which ultimately result in less crop production and less income. The use of tractors in our country is more for commercial purposes than for agricultural purposes. One of the main reasons for non-availability of agricultural implements is the small average farm size. On average more than 90% of farmers in Pakistan have less than 5 acres farms. The farmers have less resources and income. The poor farmers could not invest in the purchase of valuable agricultural implements and the prices are beyond their reach. Even most of the farmers are not able to get the cultivating machinery on rent basis. The available permanent raised bed machinery including three sets of bed formers and seeders capable for maize-wheat cropping system. There is a need to multiply these machines locally and make it more versatile for more crops. The machines need to be modified according to the local conditions, according to farmer's demands. The government should undertake measures and encourage the private sector to provide the raised bed machinery available to the farmers at cheaper rates.

Cropping Pattern

Generally, the farmers have tendency of growing different crops, vegetables and fodder depending on the market conditions and their demands. This tendency is more in smaller farmers than large landowners. They did not recommend the same bed size for all crops and vegetables. That is why they prefer to make new beds. This problem could be resolved if the farmers manage their cropping pattern on whole farms area with respect to their crops demand keeping in view the possible crop rotation on the same size of permanent raised beds. In this way the farmers could be benefited more from permanent raised beds.

Weeds Infestation

It has been determined from the last four to five years research that raised beds have about 30-40% less weeds infestation than the traditional flat basin (Ghani and Zahid, 2006). It was observed during the study that the farmers mostly did not care much for weeds control in their traditional farming. They did not know how to control the weeds effectively. They mostly get rid of weeds at the end of crop season after harvest by rotary hoeing their fields. This practice did not favour the permanent raised bed farming. The weeds problem is more severe during maize crop. It is very difficult for the machinery to perform smoothly in the presence of grasses and other weeds left after maize harvest that causes sowing of wheat crop very difficult. The seeder press wheels (Seed delivery system into the soil) are placed closer together for planting wheat crop rows. The weeds get trapped into the press wheels and the soil starts dumping in front of the seeder causing the sowing operation very difficult. This was one of the important reasons that compelled the farmers to destroy their beds and make fresh beds again causing more cost. Thus the farmers have to control the weeds chemically and manually during crop season to reduce their damage to crop as well as to facilitate the permanent raised bed-farming operations.

Farm Sizes and Tenancy Rules

The farm sizes in Pakistan are very small and the smaller farmer's economies are not of scale so they are not able to shift from traditional way of farming to modern techniques on the basis of economic values. It was observed that the smaller farmers are not able to invest more. Consequently they are compelled to compromise on yields and outputs. It was specially observed in the study area that the tenancy rules did not facilitate the tenants for adoption of a modern technology that could increase the benefits on a longer sustainable basis. This problem could be resolved by making cluster of farmers' where all the farmers could contribute according to their economy and government should provide financial resources, technical guidance and subsidies in its adoption.

Headland Problem

The raised beds are made parallel to one another. The tractor has to take a U-turn at the end of each pass. Thus tractor-turning area is called headland and remains uncultivated. The length of headland is generally 3-4 m depending on tractor and machinery size. This headland is covered by the farmers most often by perpendicular passes to the raised beds and some time they cultivate it manually by extending the raised beds to the field end. This takes extra time especially in smaller fields and farmer could hardly afford it. However,

it is recommended that the field size should be large enough so that the land lost in headland become non-significant. Field size should be such that land lost as headland should not exceed 10% of total field area. If a farmer afford to leave some area permanently uncultivated at both ends of permanent raised bed field as head land then it might be a nice solution. Because in this way the farmer will also be able to perform mid season operations like fertilizer, weedicides and pesticides application and mechanical weed control *etc.,* by using tractor and machinery.

Subbing

Lateral movement of irrigation water wetting front from furrows to the centre of raised bed is called subbing. The raised bed specifications should be adopted keeping in view the soil type, slope, crop type, water availability, machinery limitations etc. We have reached to the conclusion after having research on different sizes that the size should fit the gap in wheels of MF 240 or FIAT 480 tractors. These are the most common tractors available in Pakistan for farming. The two possible widths of beds with this arrangement are 130 cm and 65 cm from centre to centre of furrows. The wide 130 cm bed can accommodate five rows of wheat and two rows of maize while the narrow 65 cm bed can accommodate two rows of wheat and one row of maize. We have observed in last eight to nine years of research that larger sizes of beds results subbing problem and consequently yield reduction. For row crops the bed size is not a major problem as the crop is established on beds edges, which did not face any water shortage, but especially the wheat crop on the centre of the bed suffers water shortage if bed size is wider. The subbing problem become more severe as the season progresses and the bed consolidates. The tractor movement in the furrows consolidates the furrows that cause reduction in the vertical infiltration of furrows resulting facilitation in lateral wetting front movement into the raised bed.

Seasonal Land Leveling

It was observed during the study that some of the farmers in their traditional farming do land leveling manually or mechanically for next crop seedbed preparations. This did not support permanent raised bed planting. The farmers have to level (laser level if possible) the filed once before raised beds formation and then will not disturb the beds seasons after seasons. It is the duty of expert tractor operator to keep the level of the furrows and beds sustained by careful selection of tractor pass direction during permanent raised bed renovation. The tractor should reverse the direction in each bed season after season and should not follow the same direction each time. In this way the soil collected towards the headland will be less and leveling will not be disturbed.

Lack of Awareness

Beside the poor economic aspect of our farmers they are also not aware of most of the modern techniques developed recently. The farmers have still the misconception that there is loss of cropland in raised beds due to empty furrows. There is a need of farmers training and changing their mindset. It is the duty of researchers, scientists and agricultural extension workers to transfer the new technologies to the farmers and let them aware of the causes and reasons of less crop production. The farmers have to adopt the new techniques and methods to make their farming more productive and profitable.

Other Miscellaneous Factors

As the permanent raised bed farming necessitates the need to follow mechanized way of farming from sowing to harvest. Its benefits will be more prominent if we make our farming mechanized. During this study it was learnt that only 5 to 10% of farmers are using recommended doze of fertilizers. Using better quality seed, recommended dose of fertilizers according to need, better weeds and pest control, timely irrigation *etc.,* will make permanent raised bed farming a profitable business. It is therefore essential to make the permanent raised bed machinery locally at cheaper rates. The seeders must have the quality of precision planting especially for some row crops. In this way the farmers' confidence will be established and they will not hesitate in adopting permanent raised bed technology.

CONCLUSIONS

The farmers using permanent raised bed farming system saved about 36% water for wide beds and about 10% for narrow beds and grain yield

increase of about 6% for wheat crop and 33% for maize crop was recorded. The percent of cluster farmers that have adopted the technology on seasonal basis are in the range of 35% for wheat and 77% for maize. The farmers that have adopted the permanent raised bed technology for both crops and are still practicing it are about 16% of both clusters farmers. The reasons for less adoptions were less weeds control, non-compatible cropping pattern, no use of recommended dozes of all farm inputs, small farm sizes, problems in tenancy rules, lack of awareness and technical skills of farmers, lack of proper local made raised bed machinery availability up to the satisfaction of farmers and mechanization of farming system from sowing to harvest.

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